trench forming step of forming a trench in the first epitaxial layer; a second epitaxial layer forming step of forming a second epitaxial layer on the first epitaxial layer and in the trench, by introducing a dopant gas of a second conductivity type that is different from the first conductivity type at a predetermined first dopant gas flow rate, in an atmosphere of a predetermined first temperature; and a third epitaxial layer forming step of forming a third epitaxial layer to fill up the trench, by introducing the dopant gas of the second conductivity type to the second epitaxial layer at a second dopant gas flow rate that is greater than the first dopant gas flow rate, in an atmosphere of a second temperature that is higher than the first temperature.

[0015] According to a seventh aspect of the present invention, in the method of producing a semiconductor substrate as described in the fourth aspect, it is preferable that amount of dopant in the second epitaxial layer, the third epitaxial layer, and the fourth epitaxial layer is changed by changing the flow rate of the dopant gas of the second conductivity type.

[0016] According to an eighth aspect of the present invention, in the method of producing a semiconductor substrate as described in the fourth aspect, it is preferable that amount of dopant in the second epitaxial layer, the third epitaxial layer, and the fourth epitaxial layer is changed by using a plurality of gas cylinders of different concentrations of the dopant gas of the second conductivity type.

[0017] According to a ninth aspect of the present invention, in the method of producing a semiconductor substrate as described in the fourth aspect, it is preferable that at least one of the second epitaxial layer, the third epitaxial layer and the fourth epitaxial layer is formed by feeding a material gas and a halide gas in parallel in the atmosphere.

[0018] According to a tenth aspect of the present invention, in the method of producing a semiconductor substrate as described in the fourth aspect, it is preferable that amount of dopant is substantially the same in the second epitaxial layer, the third epitaxial layer and the fourth epitaxial layer.

[0019] According to an eleventh aspect of the present invention, in the method of producing a semiconductor substrate as described in the fourth aspect, it is preferable that a flow rate of a halide gas in the atmosphere is greater in the third epitaxial layer forming step than in the second epitaxial layer forming step and the fourth epitaxial layer forming step.

[0020] In a twelfth aspect of the present invention, a semiconductor substrate is manufactured by the method of producing a semiconductor substrate as described in the first aspect.

[0021] In a thirteenth aspect of the present invention, a semiconductor device uses the semiconductor substrate as described in the twelfth aspect.

Effects of the Invention

[0022] The present invention is aimed at providing a semiconductor substrate, a semiconductor device and a method of producing a semiconductor substrate that are more likely to provide desired electrical characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. **1** is a partial cross-sectional view schematically showing an embodiment of a semiconductor substrate according to the present invention;

[0024] FIG. **2** is a flow chart showing an embodiment of a method of producing the semiconductor substrate according to the present invention;

[0025] FIG. **3**A is a partial cross-sectional view sequentially showing changes in a cross section of a semiconductor substrate **1** in the method of producing a semiconductor substrate shown in FIG. **2**;

[0026] FIG. **3**B is a partial cross-sectional view sequentially showing changes in a cross section of a semiconductor substrate **1** in the method of producing a semiconductor substrate shown in FIG. **2**;

[0027] FIG. **3**C is a partial cross-sectional view sequentially showing changes in a cross section of a semiconductor substrate **1** in the method of producing a semiconductor substrate shown in FIG. **2**;

[0028] FIG. **3**D is a partial cross-sectional view sequentially showing changes in a cross section of a semiconductor substrate **1** in the method of producing a semiconductor substrate shown in FIG. **2**;

[0029] FIG. **3**E is a partial cross-sectional view sequentially showing changes in a cross section of a semiconductor substrate **1** in the method of producing a semiconductor substrate shown in FIG. **2**;

[0030] FIG. **4** is a partial cross-sectional view schematically showing an embodiment of a semiconductor device according to the present invention; and

[0031] FIG. **5** is a partial cross-sectional view schematically showing another embodiment of a semiconductor device according to the present invention.

PREFERRED MODE FOR CARRYING OUT THE INVENTION

[0032] A semiconductor substrate of the present invention is described hereinafter with reference to the drawings. FIG. **1** is a partial cross-sectional view schematically showing an embodiment of a semiconductor substrate according to the present invention.

[0033] As shown in FIG. **1**, in the semiconductor substrate **1** of the present embodiment, a first epitaxial layer **11** is formed on a silicon substrate **10** and a plurality of trenches **12** is formed in the first epitaxial layer **11**. In the trenches **12**, a second epitaxial layer **13**, the third epitaxial layer **14** and a fourth epitaxial layer **15** are sequentially formed. In addition, the fourth epitaxial layer **15** is formed also on the first epitaxial layer **11**.

[0034] The silicon substrate **10** is an n+ type silicon substrate to which an n-type dopant is introduced to single crystal silicon at a high concentration. The first epitaxial layer **11** is formed on the silicon substrate **10**. The first epitaxial layer **11** is an n-type silicon epitaxial layer to which an n-type dopant is introduced at a lower concentration than in the silicon substrate **10**.

[0035] The plurality of trenches **12** is formed in the first epitaxial layer **11**. A bottom face of the trenches **12** is a main surface of the silicon substrate **10**. The trenches **12** are substantially in a rectangular pole shape. A side face of the trenches **12** is an inner side face of the first epitaxial layer **11**. The second epitaxial layer **13** is formed on a main surface of the first epitaxial layer **11** and in the trenches **12**. The second epitaxial layer **13** is a p-type silicon epitaxial layer to which a p-type dopant is introduced.

[0036] The third epitaxial layer **14** is formed on the second epitaxial layer **13**. The third epitaxial layer **14** is a p-type silicon epitaxial layer to which a p-type dopant is introduced.